Preliminary Personal Rapid Transit Feasibility Study

The Mountain Post

Fort Carson, Colorado

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Executive Summary

The United States Army Garrison (USAG)- Fort Carson, CO, The Mountain Post, has adopted sustainability performance objectives which include reducing single-occupant vehicle non-mission trips per capita from 2008 baseline 40% by 2017. Fort Carson transportation planners estimate that the Pedestrian and Low-impact Vehicle system plan is likely to divert at least 8% of non-mission auto trips on the installation to walking or low-impact vehicles. This preliminary study investigates whether a personal rapid transit (PRT) system can accommodate the remaining 32% and how the costs of such a system compare to the benefits. Finally, it briefly examines the possibility of such a system being financed through fare-box revenues.

At least four PRT vendors exist with systems that have been developed to the point of having full-size prototypes. At least two of these have commercial customers and are producing systems anticipated to be publicly operating within the next twelve months. A survey of participants at a public meeting held on-Post indicated a strong preference for PRT over other modes of transit. This was based on features including: flexible departure and arrival, low cost, easy to use, short walking distance, short waiting time, energy efficient, short travel time, low emissions, no transfers, consistent travel time, safe, comfortable, visually appealing, seated travel, ADA compliant, personally secure and private.

Based on trip generation numbers developed by Jacobs Engineering that assume approximately 100,000 daily Post entries, a PRT system that would accommodate a 32% mode share, a PRT system would have to have 800 T-Pods, 23 miles of guideway and 35 stations carrying 16.93 million annual passengers. This mode share is unlikely to occur naturally and some form of PRT incentive/automobile disincentive program will likely need to be developed.

The PRT system is estimated to cost $494.30M (million) and to require additional parking lots costing $28.10M. However, it is expected to obviate the need for road improvements costing $11.58M and parking lots costing $132.92M (some of which already exist). The annual system operating and maintenance costs are anticipated to total $21.16M. This is partially offset by reduction in annual road and parking lot maintenance of $7.22M. Other quantified benefits include travel time, automobile costs, emission reductions and accident costs totaling $76.13M annually. Quantified benefits are found to outweigh costs (including annualized capital costs) by a factor of 2.35. A $1.66 per-ride fare is found to cover annualized net capital costs plus operating and maintenance costs. For federal employees, the monthly transit allowance of $230 would cover 138 such trips.

The present study is of insufficient depth to provide the level of credibility needed for a final decision to proceed. However, the results are quite positive and provide strong support for further analysis. Quick action is recommended in order to avoid growth-responsive road and parking expansion projects from eroding the benefits of a PRT project.

Introduction

In 2002, the USAG - Fort Carson, CO (near Colorado Springs), The Mountain Post (hereafter "Post") adopted a year 2027 sustainable transportation goal and performance metrics for the installation:

- Goal: Reduce automobile dependency, and provide balanced land use and transportation systems.
- Performance metrics:
  - 20% per capita reduction in vehicle miles traveled on Post by 2015, and 40% by 2027;
  - 20% of total trips on Post using alternative modes by 2015, and 40% by 2027;
  - Alternative mode network in place by 2015.

In 2007, year 2012 objectives were adopted which include significant reductions in single occupancy vehicle (SOV) use among several sustainability performance objectives:

- Reduce single-occupant vehicle non-mission trips per capita from 2008 baseline:
  - 25% by 2012
  - 40% by 2017
- Regarding sustainable transportation fuels, achieve the following by 2012:
  - 100% access by Fort Carson users to cost-effective sustainable transportation fuels
    - Reduce lifecycle fossil-fuel inputs and greenhouse gas and any regulated emissions of transportation systems and encourage Fort Carson personnel to do the same in their personal lifestyles.
  - 10% annual increase in non-petroleum fuel usage from 2006 baseline
  - 2% annual decline in petroleum usage by Fort Carson non-mission operations from 2005 baseline

Other Fort Carson Sustainability Goals bear upon its transportation system:

- Goal 1 – Energy and Water – calls for the installation to be fully powered by renewable energy by 2027, with the amount coming from power produced on the installation to be maximized.
- Goal 5 – Hazardous Air Emissions – calls for achievement of zero hazardous air emissions by 2027; presently ~85% originate from transportation-related sources.
- Goal 6 – Sustainable Master Plan – calls for integration of sustainability principles into land use planning on the installation

These goals are supported by Federal Government, Department of Defense and Department of the Army policies and goals, notably Executive Order 13423 that calls for the Federal Government to be sustainably managed and reduce its energy intensity in order to reduce greenhouse gas emissions, among other goals (1).

Taken together, these sustainability performance metrics call for rapid development of a desirable, highly-energy efficient non-auto system on the Post appropriately connected to surrounding communities. From Fort Carson's viewpoint, a key strategy for achieving these performance indicators is to help Post users (Soldiers/employees, contractors, business visitors, and the approximately 80,000 additional users of Post facilities that are families of Soldiers/employees and/or military retirees) obtain access to the Post's gates and major facilities without their personal vehicles.

The Post is presently experiencing significant growth, which challenges its ability to meet its sustainability goals and objectives, yet makes achievement of a sustainable transportation system even more imperative. By 2012, active military personnel stationed at Fort Carson are expected to grow by approximately 11,000 from the 19,000 in 2006 – more than 50% growth. The Post's transportation planning is presently assuming 29,034 active military and 5,443 civilians as of 2012, a total employment force of 34,477. The Post's transportation system is also expected to fulfill the needs of 13,440 Soldiers and families living on Post.

In addition to encouraging people to share rides, the Post is considering numerous alternatives to reduce SOV trips, including providing improved sidewalks and a special right-of-way system to support the use of Low-impact Vehicles, such as bicycles (human or electricity-powered) and Segways. However, average on-Post trip lengths are about 3.5 miles long, and these alternatives will not always be appropriate (especially in times of inclement weather). Fort Carson transportation planners estimate that the Pedestrian and Low-impact Vehicle system plan is likely to divert at least 8% of non-mission auto trips on the installation to walking or low-impact vehicles.

Bus services on the installation have historically been poorly utilized and thus, traditional non-automobile transportation options seem very limited in their ability to facilitate achieving the sustainable transportation goals. Primary reasons for low use of transit options include:

- Land use patterns at Fort Carson and surrounding communities promote auto ownership and usage (including that many Fort Carson destinations are completely unserved)
- Transit services are inconvenient – requiring a transfer to a different route immediately after leaving the installation (changing slightly for 2009) – and low frequency of service
- Relatively low costs of auto ownership and usage compared to rising compensation of military and civilian personnel (especially during wartime via combat pay and reenlistment bonuses)

Personal rapid transit (PRT) is a relatively new form of transit, which utilizes small, automated vehicles travelling on guideways, to transport passengers directly to their destinations, without stopping or transferring. It provides a high level of service more akin to an automobile than a bus. Due to the automation that allows driver-less transit services, PRT is relatively inexpensive to operate. However, the infrastructure development (separate rights of way, either surface guideways with tunnels, or bridges at intersections with roadways, or a completely elevated system, PRT vehicles and stations) requires considerable up-front capital expenditure. PRT can carry significant numbers of people in all kinds of weather and, working with low-impact vehicle systems (especially low-impact vehicles serving as one-way rides to and from PRT stations), could potentially allow the Post to meet its sustainability goals. The purpose of this study is a preliminary investigation of the feasibility of a PRT system for USAG – Fort Carson with connections to surrounding communities.

This study is based on conditions as they are projected to be at build-out (approximately 2015) – also referred to, herein, as the Planning Year. It is one of several components of Fort Carson's Sustainable Transportation Plan, adopted 2009 (see website http://sems.carson.army.mil for further details).

Personal Rapid Transit (PRT) Overview

The Advanced Transit Association (2) describes modern PRT as meeting the following criteria:

1. Fully automated vehicles (no human drivers).
2. Vehicles captive to the guideway, which is reserved for their exclusive use.
3. Small vehicles, available for exclusive use, by an individual or small group traveling together by choice. Available for service 24 hours a day.
4. Small guideways can be elevated, or near ground level, or underground.
5. Vehicles able to use all guideways and stations on a fully connected network.
6. Direct origin-to-destination service, with no necessity to transfer or stop at intervening stations.
7. Service available on demand, rather than on fixed schedules

Unlike regular transit, PRT vehicles (transportation pods or T-Pods) are typically already waiting when passengers arrive at a station. If a T-Pod is not already available, one usually comes within a minute. All of the PRT systems discussed here are fully American with Disabilities Act (ADA) compliant and accommodate three or more adults with luggage.

There are currently four PRT systems that are commercially available, or close to being so. In approximate order of availability, these are:

The ULTra PRT System

Offered by Advanced Transit Systems Ltd., of Bristol, United Kingdom, the ULTra system (3) is rubber-tired, battery-powered, and runs on an open guideway. The front wheels are steerable, and the T-Pod keeps itself on the guideway without any physical lateral guidance, simplifying switching, which is accomplished by steering. This system is currently operating in test mode at London's Heathrow International Airport, where it is scheduled to go into passenger service later this year. The commitment to using off-the-shelf technology, wherever possible, coupled with a rigorous testing and development program, has allowed the ULTra system to be the first modern PRT system to win a commercial contract. Once the initial two-mile phase, employing 18 T-Pods, has proven successful, Heathrow plans to expand the system to 30 miles of guideway with some 400 T-Pods.

Figure 1. ULTra T-Pod operating at Heathrow.

The ULTra T-Pod was designed for four adults, plus luggage. However, Heathrow has opted to replace the bucket seats with bench seats, allowing the vehicle to carry a family of six.

Open guideway PRT, such as that used by ULTra and 2getthere, tends to be more economical, but the rubber/guideway interface can be problematic during inclement weather conditions. ULTra has plans to address this issue, by using a glass fiber reinforced plastic grating as the riding surface. Preliminary testing by PRT Consulting in the winters of 2006 and 2007 has shown this solution to be very successful in mitigating the effects of Colorado snowfall.

The 2getthere PRT System

2getthere, a Dutch company (4), has been operating an automated PRT-like shuttle bus system, in cooperation with Frog Navigation Systems in Rotterdam, Holland, for a number of years. All told, 2getthere has about ten years of experience in operating automated people movers in the public domain. However, none of these systems comply with the definition of PRT provided above. 2getthere's newly-developed PRT system has been chosen, as the primary form of internal transportation, for the new city of Masdar in the UAE. This system is planned for approximately two thousand vehicles.

Figure 2. 2getthere T-Pod

2gethere's PRT system is of the open guideway type, with somewhat similar attributes to those of the ULTra system. However, there is little information publicly available about this system.

The Vectus PRT System

Vectus (5) is a subsidiary of POSCO, one of the world's largest steel manufacturers. Despite being a British company owned and operated by Koreans, Vectus chose to establish a full-size test track, with an off-line station, in Sweden, in order to prove operability in winter weather conditions and to meet the rigorous Swedish safety requirements. They now appear to have accomplished both of these goals.

Figure 3. The Vectus T-Pod and station.

The Vectus (and Skyweb Express) system is of the captive-bogey type, where the undercarriage, or bogey, is not steerable, but has wheels which run along vertical side elements, thus, keeping the T-Pod on the guideway. Switching is accomplished by movable wheels mounted on the T-Pod. The T-Pod is propelled (and braked) by linear induction motors, which are mounted in the guideway. Mounting the motors in the guideway reduces the weight of the vehicles, but increases the cost of the guideway. This is advantageous for high-capacity systems, but expensive for low-capacity systems. Propulsion batteries are not required, allowing the T-pods to be lighter-weight.

The Vectus T-Pod is designed to carry four adults, plus their luggage. They have recently been selected to construct a PRT system in Suncheon, Korea.

The Skyweb Express PRT System

The Skyweb Express system is offered by Taxi 2000 (6), a Minnesota company. It is of the captive-bogey type but, unlike the Vectus system, has the linear induction motors mounted in the T-Pods. The motors obtain power from the guideway, so propulsion batteries are not required. Switching is by movable vehicle-mounted guide wheels. The T-Pod is designed to mimic the back seat of a taxi and, as such, has a three-cushion tilt-up bench seat designed for three adults.

Figure 4. The Skyweb Express T-Pod.

Taxi 2000 has a sixty-foot guideway, with a full-size T-pod, constructed and operating in Fridley, MN. However, the test track does not demonstrate switching capabilities. It is not known if they have any commercial customers; they are working on a PRT system in Dubai.

Comparison with Other Potential Fort Carson Modes

This section compares PRT with other modes of travel, from two points of view. First, and most importantly, the point of view of existing Fort Carson commuters is evaluated. Second, PRT is compared with transit and automobiles in a scientific way.

Transportation Preferences of Fort Carson Commuters

A Transit & Parking Options Workshop, open to Fort Carson leaders, employees, residents, soldiers and community stakeholders, was held on 1 October, 2008 from 0900 to 1500. There were 21 participants, of which one was a Soldier living on Post. Participants were exposed to descriptions of numerous transportation options. Most of these descriptions were fairly brief, since most options (such as buses) were already familiar to the participants. Where options were typically unfamiliar (such as PRT), a more in-depth description was provided. Participants were given the opportunity to ask questions and take part in discussions. During the workshop, participants responded to a number of questionnaires, the results of which are tabulated and discussed below.

Table 1. Travel Pattern Survey

Travel Pattern Survey Summary			
Survey #	Description	No. of Parking Spaces used	Note
1	PPACG Staff Member	1	Rarely visits Post
2	Civilian	3	POV to/from post then GOV vehicle
3	Civilian	0	Bus only
4	Civilian	0	visits base 1 time per month via GOV
5	Civilian	5	POV to/from post then GOV vehicle
6	Student/Intern @ UCCS	0	N/A - did not consider base visit
7	Civilian	1	POV only
8	Civilian	4	POV only
9	Civilian	5	POV & GOV use
10	Civilian	2	POV to/from post then GOV vehicle
11	Civilian	4	POV only
12	Civilian	1	POV only
13	Civilian	3	POV only
14	Civilian	5	POV to/from post then GOV vehicle
15	Civilian	3	POV only
16	Civilian	3	POV only
17	Civilian	2	POV only
18	Soldier Living On-Post	6	POV only
19	Civilian	2	POV only
20	Civilian	2	POV only
21	Civilian	2	POV only
Average Parking Stall Requirement		2.6	

Table 1 categorizes the workshop participants. It also shows that people who drive on the Post typically use more than one parking stall. In fact, if the four people, that indicated they rarely travel to the Post or use the bus, are eliminated, the results indicate that drivers on the Post use more than three parking spaces on average.

Table 2. Travel Preference Survey

Travel Preference Survey Question:
Please vote on which of the following transportation characteristics are most important to you for Post-related trips. You have a total of 100 votes. You may not use more than 25 votes on any one characteristic. Ordered from most to least important.

Ordered Travel Preference Survey Analysis Results		
Reliable	13.22	Highest Priority
Flexible Departure and Arrival	10.22	
Low Cost	9.50	
Easy to Use	9.22	
Short Walking Distance	7.72	
Short Waiting Time	7.61	
Energy Efficient	6.72	
Short Travel Time	6.39	
Low Emissions	4.56	
No transfers	4.39	
Consistent Travel Time	4.17	
Safe	3.72	
Comfortable	3.44	
Visually Appealing	2.67	
Seated Travel	2.28	
ADA Compliant (disabled persons access)	1.94	
Personally Secure	1.94	
Private	0.28	Lowest Priority
Total	100.00	
Median	4.47	
Mean (Average)	5.56	
Average Deviation	2.91	
Standard Deviation	3.48	

This survey sought to discover which transportation characteristics were most important to participants. Prior to the survey, participants were given the opportunity to modify and/or add to the list of characteristics.

Table 3. Transportation Options Survey

Transportation Options:

Please rank the following transportation options from 1 (best) to 17 (worst) based on your perception of the ability of each option to meet your desired travel characteristics for Post-related trips.

Travel Preference - Transportation Options Analysis Summary			
Average Rank Sorted From Lowest (best) to Highest (worst)		Standard Deviation	Mode (highest frequency of ranking number)
Travel Mode	Average Rank		
Personal Rapid transit	3.3	3.1	1 (Best)
Low Impact vehicle	5.8	4.5	4
Shuttle Bus	6.2	3.4	5
Car	6.8	5.3	1
Bicycle	7.8	5.8	2
Express / Regional Bus	7.8	3.5	9
Walk	8.1	4.9	1
Bus Rapid Transit	8.1	6.0	11
Local Bus	8.1	5.1	3
Jitney	8.4	3.8	11
Monorail	10.3	3.8	10
Light rail	10.5	3.4	14
Paratransit	11.2	2.8	11
Commuter Rail	11.4	3.6	14
Maglev	12.2	3.5	15
Heavy Rail	13.2	3.2	16
High Speed rail	13.8	3.5	17 (worst)

Note that participants were rating the transportation options based on their individual Post-related travel requirements. These varied substantially in trip length.

Since the focus of this study was on-installation travel, it was decided to calculate mode preference for on-installation trips only. Since there was insufficient time to have the participants do this, we (PRT Consulting) rated each Mode against each characteristic, shown in Table 2, on a scale of 1 (poor) to 5 (excellent). For example, the mode "bicycle" was rated 5 for low emissions and 2 for safety. Note that we assumed trip lengths of 1/2 to 10 miles.

Each rating was then multiplied by the average number of votes that characteristic received. For example, the bicycle rating of 5 for low emissions was multiplied by the 4.56 average votes for low emissions, for a score of 22.8. The scores for each mode and each characteristic were then added to arrive at the score in the Table 4 below (540 for bicycle).

Table 4. Mode Preference

Mode Preference	
Mode	Score
Personal Rapid Transit	661 (Best)
Low Impact Vehicle	588
Car	572
Bicycle	540
Walk	532
Jitney	467
Light Rail	467
Monorail	451
Commuter Rail	451
Paratransit	443
Maglev	443
Heavy Rail	435
High Speed Rail	435
Bus Rapid Transit	403
Express / Regional Bus	387
Shuttle Bus	387
Local Bus	346 (Worst)

While PRT and car again scored high, the relationship between rail and bus modes changed quite considerably. The table has been colored to highlight the result, that all small vehicle modes outscored all rail modes, which in turn outscored all bus modes (except paratransit).

In summary, although the attendance was insufficient and too homogenous to provide scientifically valid data, there was fairly clear evidence of preference for small vehicle modes, responsive to individual transportation demand, and resistance to bus modes that are inflexibly responsive to transportation demand. However, one anomaly was that shuttle bus ranked third highest in Table 3, yet second lowest in Table 4. The reasons for this are not understood. However, as noted previously, bus services on the installation have historically not been well patronized.

Scientific Comparison

In the discussion which follows, PRT is compared with car and transit (light rail or bus) for a number of different attributes. For each attribute, each mode is rated Poor (red), Fair (yellow), or Good (green), on the summary (Table 5) overleaf. Note that this is a generic discussion and is not adapted to be installation-specific.

Transit Car PRT

New Technology

Transit systems and autos are both mature industries. PRT has been operating since the early 1970's, in the form of the Morgantown, WV system. Although this system overran its initial schedule and capital budget, it has since performed well and has proven the basic PRT concept. It has completed over 140 million injury-free passenger miles at a current operating cost of about $1.50 per passenger. As described elsewhere, there are now a number of commercially-available PRT systems, and the first modern PRT system is scheduled to come into operation later this year.

Table 5. Benefit Comparison

Benefit Comparison

Benefit	Transit	Car	PRT
New technology	Good	Good	Fair
Trip Time	Poor	Fair	Fair
Cost per passenger	Fair	Fair	Good
On-demand 24/7	Poor	Good	Good
Transfers	Poor	Good	Good
Seated travel	Fair	Good	Good
Private	Poor	Good	Good
Non-stop	Poor	Fair	Good
Vehicle waits for passenger	Poor	Good	Good
ADA compliant	Fair	Poor	Good
Safe and secure	Fair	Fair	Good
User friendly	Fair	Fair	Good
Snow & ice	Fair	Poor	Fair
Minimal walking	Poor	Good	Fair
Environmentally friendly	Fair	Poor	Good
Energy efficient	Fair	Fair	Good
Visually appealing	Fair	Fair	Fair
Operates inside buildings	Poor	Poor	Fair

Legend: **Poor** (red) **Fair** (yellow) **Good** (green)

Transit	Car	PRT

Trip Time

Automobile trips in urban areas do not typically result in low travel times, because of the numerous stop signs, traffic lights, and often congested roadways, that have to be negotiated. This is true even for trips that are undertaken at high speeds on freeways, since low speed segments at each end of the trip invariably offset these high-speed trip segments. Analysis of trips at all times of the day - in the Denver Metropolitan area - reveals that trips shorter than about twelve miles are undertaken at average speeds of less than 30mph. Bus speeds over a twelve mile route average approximately 16mph.

Light rail (LRT) seems fast with its 55mph maximum speed, but this is impacted by the numerous stops that must be made. The 12.5 mile light rail trip from Mineral Station to Downtown Denver is scheduled for an average speed of 26mph.

A PRT system, with a maximum speed of 35mph, will average about 32mph over a twelve mile trip. This takes account of acceleration and deceleration at the origin and destination, as well as the fact that there will be no intermediate stops. It also takes account of the extra travel distance of approximately one half mile, due to a one-way guideway system, with guideways and stations at half mile intervals.

Thus, a PRT system with a maximum speed of 35mph can be expected to have faster travel times than LRT, bus or car, over a distance of less than about twelve miles in an urban setting.

However, travel time is only part of the total trip time. Buses and LRT almost never pick up their passengers at their homes and deposit them at their workplaces. Even cars have to sometimes be remotely parked. Almost all public transit trips involve walking segments, at the beginning and end, and many also require transfers. PRT networks should be built on a spacing of approximately one half mile, so that stations are located throughout the service area. If this is accomplished, the maximum walking distance should be about one quarter of a mile, and this portion of the trip should take less time than on other forms of transit.

Another aspect of total trip time is the time spent waiting for transit. Few transit systems have times between vehicles of less than 5 minutes during peak periods. Off peak, this can increase to half an hour or more. PRT systems are designed, such that T-Pods are usually already waiting at stations during off-peak periods, and so the average wait times should be less than one minute, at any time of the day or night.

When all of the above factors are considered, total trip times for PRT in urban settings are much closer to total trip times for cars than transit. These PRT trip times are still not considered “good” relative to what people want from urban transportation systems. Good city-wide trip times will become available when a one half-mile PRT guideway grid covers a metropolitan area, and PRT maximum speeds exceed 40mph. On-Post trip lengths are short enough that a 25 mph PRT system will provide satisfactory trip times (comparable to automobile times).

Transit	Car	PRT

Cost per Passenger

Transit costs have two basic components – capital cost for the initial vehicles and infrastructure, and operating and maintenance costs for running the system. Operating costs are somewhat less complex and will be dealt with first.

The current cost of operating and maintaining the Morgantown people mover system is $1.50 per passenger. This includes both the vehicles and the infrastructure. It compares with $4.63 (7) per passenger for the Denver Regional Transportation District (note that ticket prices are subsidized below cost by tax revenues). While this RTD figure includes buses and the light rail trains and infrastructure, it does not include maintaining the streets the buses run on, whereas the PRT costs do include PRT infrastructure maintenance.

The cost of operating and maintaining an automobile is estimated to average 54.1¢ per mile (8). This exceeds the Morgantown costs for trip lengths exceeding 2.8 miles. It also excludes the cost of maintaining the road system used by automobiles; though it includes gasoline taxes that partially cover those expenses.

The per-ride operating costs of some transit systems are provided below:

Morgantown PRT	$1.50
Denver International Airport (DIA) Automated People Mover	$0.61
DIA shuttle bus	$3.50
Denver Regional Transportation District (Bus & Light Rail)	$4.63

Since modern PRT systems are expected to function at least as efficiently as Morgantown, it seems clear that operating costs should be very competitive with other forms of transit and with automobiles.

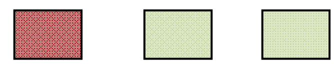
Capital costs are somewhat more complicated to compare. First, one has to prove that one PRT guideway can carry approximately the same number of passengers as one light rail line, under the same conditions of waiting and travel times. If one guideway has similar capacity to one rail line, then it is easy to see that the tiny T-Pods (compared to the heavy "light" rail cars) will require much less infrastructure and, therefore, less capital cost. In addition, although there are many more T-Pods than rail cars required, their total weight is less than the total weight of rail cars. This, combined with the economies of mass-producing many small vehicles, should result in lesser capital cost, too.

When compared with the infrastructure required for automobiles, T-Pods require much less width, because they are automatically (and therefore much more accurately) controlled. A T-Pod guideway should only need to be about seven feet wide, compared to the eleven to twelve feet width of a typical highway lane. The cost savings of the narrower guideway will be somewhat offset by the extra cost of other appurtenances required to support automation. If the guideway needs to be elevated, then the costs may well exceed those of a highway lane. A subterranean PRT tunnel (like an underground subway) will probably be even more expensive than an elevated guideway (and for this reason, none are presently proposed.)

On the other hand, a PRT tunnel or elevated guideway should be much less expensive than an automobile tunnel or elevated roadway, because of the narrower width, the reduced need for ventilation, and the restricted height and weight of the vehicles.

Because a typical T-Pod will undertake fifty or more trips per day, the total number of vehicles needed will be much less than the number of automobiles needed to meet a similar travel demand (it is estimated that automobiles are unused more than 90% of their lifetimes – making them a huge underutilized capital cost for individual owners – costs that only make sense to bear if alternatives, like PRT and user-friendly pedestrian and low-impact vehicles systems, are unavailable.) Thus, PRT will result in a savings in vehicle costs (for individuals and fleets) and a related savings in parking facilities needed.

Transit **Car** **PRT**



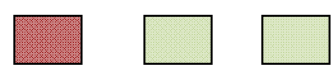
On-Demand 24/7

Transit systems usually only provide frequent (5 minutes or less) service during peak periods. The service typically gets less and less frequent away from peak periods and is often totally non-existent in the early hours of the morning. On the other hand, automobiles are available all of the time.

PRT systems are designed and operated in such a way that empty T-Pods are automatically routed to empty stations where they will wait for passengers. Except during heavy peak periods, passengers arriving at a station should be able to immediately board a waiting T-Pod. During off-peak periods, empty T-Pods will be stored at stations, waiting for passengers, in a maintenance facility and/or in a storage area. There will be no need for a large system to ever shut down.

In a network layout guideway, segments can be shut down with little impact on the remaining system (especially off peak). Only the stations associated with that particular guideway segment would be put out of service.

Transit **Car** **PRT**



Transfers

Unlike transit, cars and fully developed PRT systems should seldom require transfers. Transfers from other systems to PRT, or even among different PRT systems, should be relatively convenient, because the close station spacing will provide numerous options, and the minimal waiting time will reduce disruption to travel.

Transit Car PRT

Seated Travel

Both cars and PRT systems are designed for seated travel only. This allows vehicles to accelerate and decelerate more rapidly. Transit provides seated travel, much of the time, except during peak periods when most travel actually occurs.

Transit Car PRT

Privacy and Personal Safety

Except for systems specifically designed to operate differently (in airports, for example), PRT systems will be operated on the basis of people only traveling together if they know each other and have the same destination. While this does mean that T-Pod occupancies will be low, it also ensures privacy and a non-stop trip.

All T-Pods will have alarm buttons and, possibly, video surveillance. T-Pods subject to alarms could possibly be directed to stations where emergency personnel are waiting. The Morgantown experience, with the PRT system often used by college students, has shown an exemplary personal safety record over thirty years, with only 2 incidents, each limited to verbal harassment.

Transit Car PRT

Non-stop Travel

Transit has been rated more negatively than cars, because much transit travel is done in buses, which stop more frequently than cars. However, light rail may stop less frequently than cars. T-Pods are designed never to stop from origin to destination.

PRT systems are usually designed with all stations “off line” (see Fig. 5). This means each station is like a rest stop on a freeway with its own off- and on-ramps. Thus, T-Pods in a station are bypassed by others not needing to stop at that station. Some systems can even allow each station bay to be off line from the others (see Fig. 6). In this way, someone taking a long time to board does not delay others using the station.

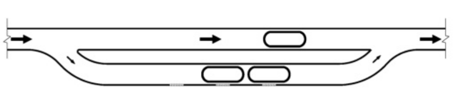


Figure 5. Off-line station with in-line bays

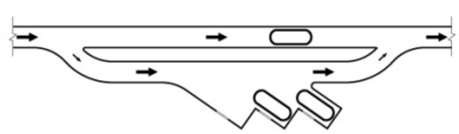


Figure 6. Off-line station with off-line bays

Transit Car PRT

Vehicle Waits for Passenger

Except for end-of-line situations, transit vehicles almost never wait for the passenger, quite the reverse is true. On the other hand, automobiles almost always wait for their passengers. This is what causes the high demand for downtown parking spaces.

PRT manages to have T-Pods waiting for passengers most of the time, while also avoiding the very low passenger to vehicle ratio exhibited by automobiles. During any one day, a T-Pod will carry many tens of passengers – possibly more than a hundred for short systems.

Transit Car PRT

ADA Compliant

Transit systems comply with the Americans with Disabilities Act (ADA), but at large expense. Light rail stations require special ramps, buses require special lifts and service must be augmented with special buses.

Automobiles do not accommodate handicapped people very well – the blind cannot drive and wheelchairs usually require special vehicles. In addition cars often require special modifications to be able to be driven by the handicapped.

On the other hand, PRT stations will allow wheelchairs (pushchairs and luggage on wheels) to easily roll on board. ULTra has demonstrated the ability for T-Pods to park at stations with less than ½" tolerance, thus, ensuring the narrowest of gaps between platform and vehicle. The ½ mile spacing of most PRT stations will also facilitate handicapped access.

Transit Car PRT

Safe and Secure

PRT systems are inherently safe because there is no crossing traffic – only merges and diverges. This is borne out by the Morgantown PRT system, which has completed over 140 million injury-free passenger miles. By contrast, other forms of surface transportation will have injured over a hundred and likely killed somebody in that many passenger miles.

By eliminating crowds at stations and in transit vehicles, PRT reduces transportation-related terrorist targets. In addition, it facilitates passenger processing by delivering a steady stream of passengers, as opposed to intermittent large groups.

Transit Car PRT

User Friendly

Transit is somewhat user friendly for non-transfer trips, but the user is required to understand routes and timetables, have exact change or a monthly pass, must often climb stairs, and has little to no storage area for bags or luggage (aside from specially designated airport vehicles).

Cars require ownership and a driver's license (which requires the ability to drive), in addition to an understanding of routes. Drivers are also frequently challenged by distractions and poor visibility due to sunshine, night blindness, etc.

PRT only requires knowledge of the origin and destination stations. People simply need to know which origin and destination stations to use, how to use a station kiosk to request a T-pod, and which button to push to begin T-Pod operation when they are ready.

Transit	Car	PRT

Snow & Ice

Transit systems vary in their resistance to snow and ice – steel wheel on steel rail systems typically have little trouble, provided grades are relatively flat, while buses will be stuck in slow traffic along with automobiles.

Inclement weather can be a major problem for autos, depending on the vehicle, the confidence and skill of the driver, and the abilities of all other drivers, some of whom are quite inexperienced with poor weather driving. Wet weather accident rates were 2.2 times the rate of dry-pavement accidents in West Virginia (9).

PRT systems are likely to be less tolerant than steel wheel on steel rail systems, but more than cars and buses. The Morgantown system has operated successfully with a heated guideway system, though this is an energy-intensive solution that goes against sustainability principles of maximizing life-cycle energy efficiency. Some PRT systems have their undercarriage almost fully enclosed by the guideway and are expected to operate with relative disregard to snow and ice.

Transit	Car	PRT

Minimal Walking

Transit typically involves quite a lot of walking. Light rail stations are typically about a mile apart. Bus stops are often within a quarter of a mile of each other, but bus routes are often more than a mile apart. Most people are located beyond reasonable walking distance (1/4 mile) from a stop or station. For example, once FasTracks is complete, 96% of the City of Denver (by area) will be more than ¼ mile from a rail station. Many are forced to park and ride.

While automobiles typically involve little walking, remote parking is sometimes required.

A good PRT system will have guideways and stations spaced at about ½ mile intervals. This should keep almost all walking down to less than ¼ mile at each trip end. However, some passengers could experience total walking distances exceeding ½ mile.

Transit	Car	PRT

Environmentally Friendly

Transit is generally considered more environmentally friendly than automobiles. This is more likely for well-patronized light rail, and possibly natural gas powered buses, than for diesel powered buses that spend large portions of the day driving around, mostly empty. A transit bus with less than 11 passengers is probably achieving less fuel efficiency per passenger than an auto with an average occupancy of 1.6 people.

The dramatic environmental impacts of automobiles are well-documented to include hazardous air emissions (from fossil fuel combustion), emissions of greenhouse gases (approximately 20 pounds of carbon dioxide per mile), and the life-cycle impacts of producing and disposing of the vehicles. More efficient vehicles are expected in the near future, including electric vehicles (powered by batteries, compressed air or hydrogen) and plug-in electric hybrids that run on electricity for all trips less than the battery range of 40-100 miles. Roads, freeways and parking lots devour a large amount of real estate, and contribute to storm water runoff problems, wildlife /pet safety problems, and frequent maintenance, costs of which have been increasing dramatically faster than costs of living and tax revenues for maintenance purposes.

In corridor or line-haul (as opposed to network) mode, PRT should be as environmentally friendly as light rail, or more so, because of the low energy use due to non-stop trips. In network mode, PRT has the potential to return some of the real estate used by roads. This is particularly true in downtown situations where one lane can only carry about 500 automobiles per hour, whereas one elevated PRT guideway has the capacity to replace a four-lane downtown road, freeing up the land for development, pedestrian malls or greenways.

Small electrically powered T-Pods will make little noise and vibration. Any pollution caused by the generation of electricity will be off site and subject to being reduced when the grid power source is upgraded for sustainability performance; e.g., renewable energy, carbon-sequestered fossil-fuel electricity generation, etc.

Transit **Car** **PRT**

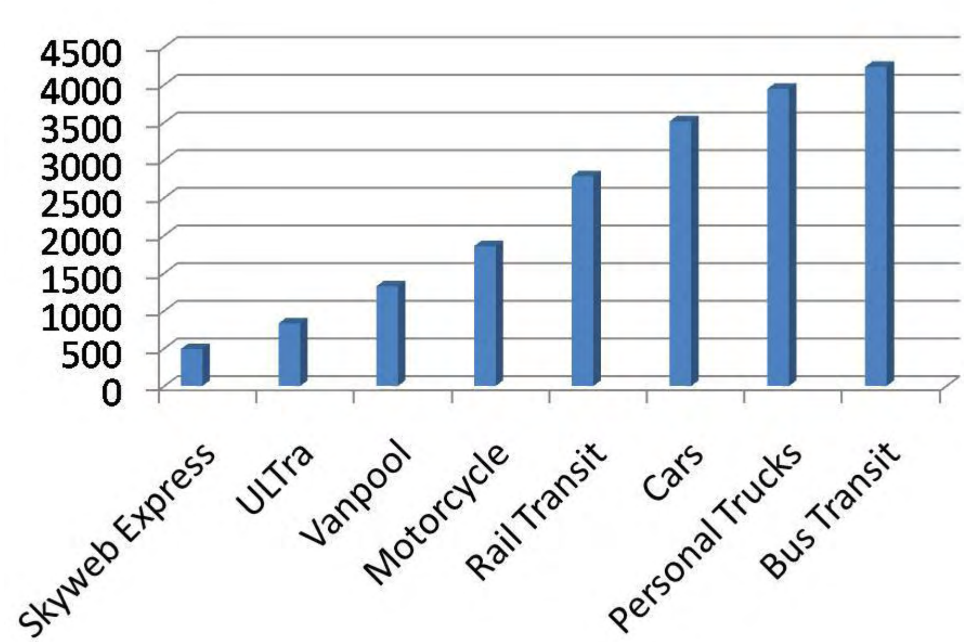
Energy Efficient

Bus-based transit is generally considered to be more energy efficient than automobiles, but as noted previously, it depends on ridership. In the Pikes Peak region, buses would be more energy efficient if transit vehicles did not have to operate mostly empty most of the day. Even during peak periods, transit vehicles generally start fairly empty in the neighborhoods and arrive downtown fairly full. They then have to return to the neighborhoods fairly empty again. Thus, even in peak periods, they are only operating half full at best.

PRT, on the other hand, is much more energy efficient for three reasons: (1) PRT travel is non-stop and so little energy is expended accelerating, and energy is generated through regenerative braking – a feature available only on electric vehicles; (2) At 25-35 MPH, PRT travel is relatively slow compared to LRT and autos on uncongested roadways, and so little energy is expended combating wind resistance (the same auto will typically get 16% more miles per gallon at 40 miles per hour than at 70 miles per hour; (10) PRT systems should have less need to move empty vehicles around in off-peak periods.

Table 6 compares the per-passenger energy use of PRT to other modes.

Table 6. Energy use (BTU per passenger mile)



Source: Skyweb Express (6), ULTra (3), USDOT (10)

Transit	Car	PRT

Visually Appealing

This is such a subjective factor that the same rating has been given to each system.

Many PRT systems will largely consist of elevated guideways. Even though these guideways will be much smaller than elevated guideways for light rail or monorail systems, they will still create a visual impact. The impact caused by curvilinear elevated guideways, snaking through a facility, may be very desirable for a theme park or possibly an airport – maybe even for a downtown area. However, it may be negatively perceived in a suburban neighborhood.

Each PRT system needs to be carefully planned so that it fits in and compliments the existing setting to the extent possible. New developments can be planned to unobtrusively accommodate guideways. This might mean planning for substantial lengths of guideways at ground level, which would also save money. On the other hand, it may mean going to the extra expense of underground guideways in sensitive areas.

Transit	Car	PRT

Operates Inside Buildings

Transit systems are typically too big to operate inside buildings, although it would be possible to incorporate a light rail station inside an airport terminal building, for example.

Unless they are electrically powered, buses and cars cannot readily operate inside buildings because of exhaust gas issues.

PRT systems are small and electrically powered and can relatively easily be accommodated inside buildings. Studies have shown that PRT systems could operate inside airport concourses, replacing moving sidewalks.

PRT vehicles parked end to end only provide a floor load of about 41pounds per square foot, which is less than the design loading for most building floors.

PRT Layout at Fort Carson

Figure 7 shows the proposed PRT guideway layout and station locations for Fort Carson. The layout was developed keeping the following considerations in mind:

- The layout was constrained to those areas of the Post generating the most traffic. For this reason zones 5 and 6 in Figure 7 are not served. Arrows at gates 1, 2, 4 and 20 are indicative of the desire to connect to other transit systems and/or to expand the PRT system off Post at some future date.
- Stations were located in such a way that walking distances exceeding ¼ mile were avoided to the extent reasonable.
- Stations were located close to proposed low-impact vehicle share locations where feasible.
- One-way guideways were laid out connecting the stations and avoiding existing structures.
- Guideway directions were determined so as to minimize out-of-the-way travel to the extent reasonably possible. In some instances, connecting loops were inserted that do not serve stations, but serve only to facilitate reversal of direction of travel.

Figure 8. Potential at-grade guideway

The layout depicted is necessarily approximate. The scope of work in this project did not allow for detailed design and the layout was only developed to the extent necessary to determine system requirements and approximate costs. Prior to implementation, much additional work will be required in order to finalize station and guideway locations and details. It will be desirable to ensure that the guideways and stations fit in well with the existing infrastructure and do not impact historic foot traffic and physical training routes. The guideway layout should be fine tuned, to eliminate sharp curves where possible, and to optimize opportunities to place it (and stations) at grade, to facilitate access and reduce costs. The addition of over-/under-passes at key intersections should be investigated to determine the impacts on capacity, number of T-Pods required and trip times. It is anticipated that this could have a significant positive impact on the circuitousness of PRT trips.

Figure 9. Potential elevated guideway

At this time, it has been conservatively assumed that 20% of the guideway and stations will be at grade, and the remainder will be elevated. Elevated guideway is much more expensive than at-grade guideway, and detailed study of this issue should be included in any follow-up work.

PRT stations at entrance gates have been located inside the secure perimeter. It has been assumed that parking lots will be located outside the secure perimeter (but within the Post fencing system). PRT users will then walk through security to enter the station. Mr. Carl Backus (11) has confirmed that this

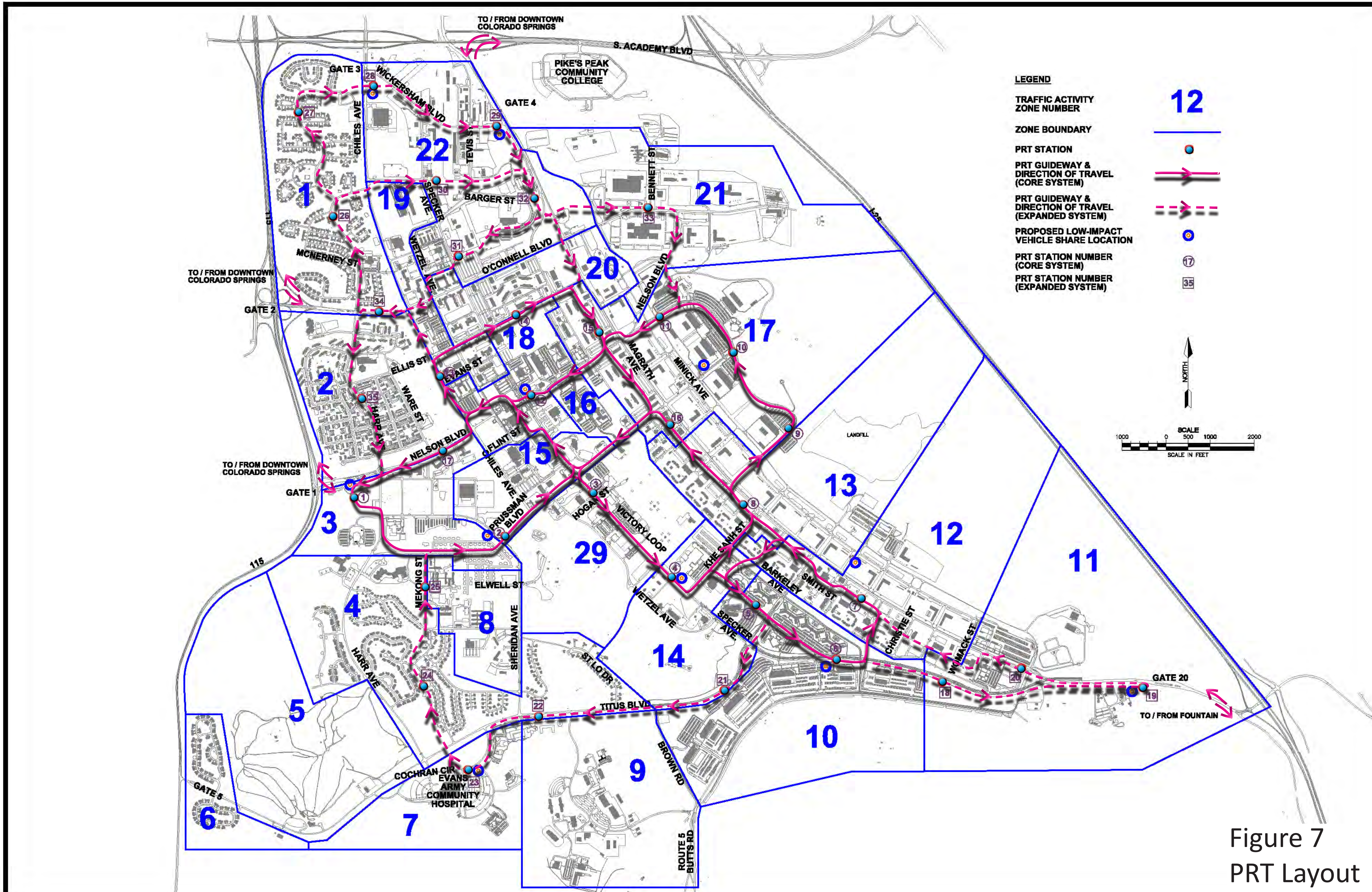


Figure 7
PRT Layout

arrangement will alleviate some of the screening burden and reduce the need to enlarge the gate facilities.

If the PRT system is ever expanded to travel off-Post, it is envisioned that riders entering the Post will exit their T-Pod to be screened and then enter a different T-Pod to continue their journey, greatly reducing the requirement to inspect the T-Pods themselves. Alternatively, weight load cells on the vehicles can sense objects left in the vehicles down to 10 lbs., and this capability can be backed up by on-board CCTV, coupled with left luggage detection software. In this way, allowing T-Pods to enter the Post should be less risky than allowing automobiles to do so.

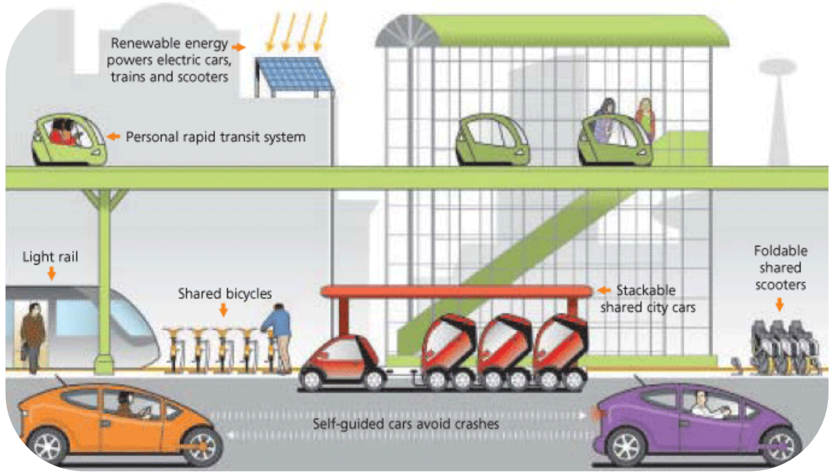


Figure 10. Intermodal station concept

Where PRT stations are adjacent to the Post's proposed Low-impact Vehicle (LIV) share locations (where a person could temporarily rent a Low-impact Vehicle for a one-way trip), it is envisioned that the LIVs will be utilized to extend the reach of the PRT system. For example, at station 23, the LIVs could be used by the disabled to get closer to the portion of the hospital they are visiting. Alternatively, they could be used to facilitate access to zones 5 and 6, which are not served by the PRT system. LIV vehicles should be of low speed and/or restricted from road travel, to avoid them being used in place of the PRT system and, thus, potentially causing traffic problems.


Figure 11. Typical elevated station

Stations 1 through 17, together with their associated 10.7 miles of guideway, are envisioned as the core PRT system – large enough to have a significant impact, yet about half the size of the expanded system with its 35-station, 22.9 miles of guideway.

It is interesting to note the core system will only carry 18% of the traffic that the expanded system will carry, using the same ridership assumptions. This is because doubling the number of stations effectively quadruples the number of station pairs available and, thus, the utility of the system. Although not analyzed, the economic viability of the core system is anticipated to be substantially less than that of the expanded system. It is shown in order to depict a way that phased construction can be undertaken. The core system will cost approximately half that of the full system.

Depending on the vendor chosen, there may be a desire to build and operate a pilot system, prior to committing to the core system, to ensure that the chosen vendor can deliver a robust system. If this is the case, the pilot system should be sufficiently large to demonstrate all of the capabilities required by the full system. A layout including stations 1, 2, 12, 13, 14, 15 and 17, along with the associated two guideway loops (4.3 miles), might be appropriate.

Figure 12. Typical at-grade station with at-grade guideway

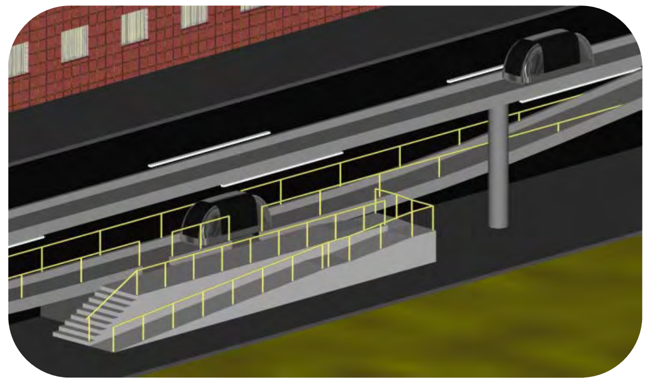


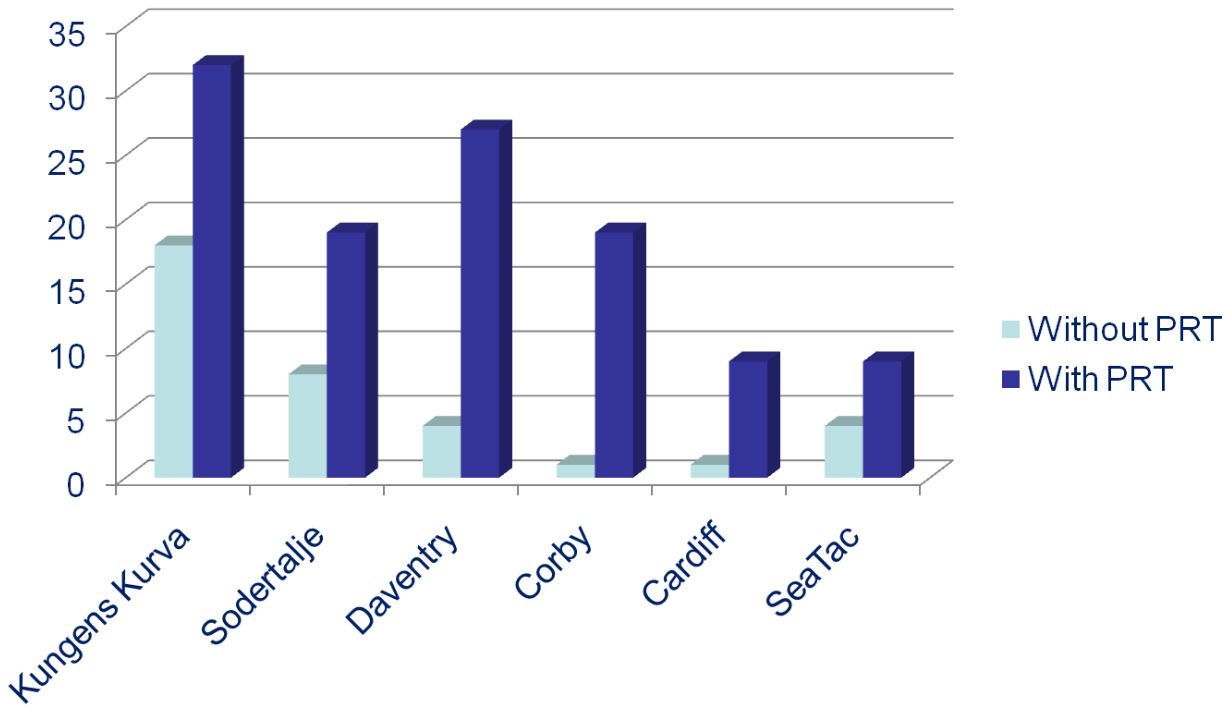
Figure 13. Typical sidewalk station with elevated guideway

PRT Ridership

The Post has an objective of reducing non-mission SOV trips by 40% per capita, by the federal fiscal year 2017. No data is available for this study as to the percentage of mission vs. non-mission trips. All trips have, therefore, been assumed to be non-mission. Since the United States has a very poor record of persuading people to reduce SOV trips by offering conventional alternatives, it has been assumed that the PRT system will have to carry the bulk of the diverted trips in order for the goal to be met. Fort Carson transportation planners estimate that the Pedestrian and Low-impact Vehicle system plan is likely to divert at least 8% of non-mission auto trips on the installation to walking or low-impact vehicles. This means the mode share of PRT must be 32%. Table 7 shows the anticipated impact PRT would have on transit mode share in various studies around the world. Only Kungens Kurva comes close to indicating a transit mode share as high as 32%, even with PRT. Clearly, some kind of PRT incentive/automobile-disincentive program will be required in order to reach this mode share at Fort Carson. Such a program is beyond the scope of this study, but has been assumed to be feasible.

Table 8 shows projected peak-hour, station-to-station, person trips the PRT system would need to accommodate. This demand matrix was derived from the inter-zonal trip demand matrix, provided by Jacobs, Inc., consultants for the installation's sustainable transportation plan, showing projected average daily person trips between each transportation analysis zone (TAZ) for the Planning Year 2015 that was used. The zones not served by the PRT system (5, 6, 23, 24, 25, 26, 27 and 28) were removed from the matrix, and the remaining trips were assigned to the appropriate station, by considering the relationship of each proposed station to the closest TAZs. Some within-zone trips were deleted to account for the likelihood of people walking short distances. To account for the proportion expected to use PRT, the remaining trips were factored by 32%. This resulted in a daily working day projected PRT ridership of 53,500. There have been assumed to be 244 working days in the year, and non-working day ridership has been assumed to be 60% of working day ridership. This results in an expected annual ridership of 16.93M.

Table 7. Transit Mode Share



Source: Various studies in the named communities.

Table 8. Projected PRT Peak-Hour Person Trips

Origin Station	Destination Station																																		Totals
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	
1	0	20	6	8	11	16	16	30	4	4	4	7	13	13	13	13	0	3	13	3	9	5	57	20	20	10	10	5	7	17	3	6	12	20	32	429
2	18	0	0	0	23	23	23	25	8	8	8	13	16	16	16	23	2	6	28	6	0	0	26	6	6	4	4	2	4	23	0	8	20	9	11	383
3	5	0	0	0	1	1	1	2	1	1	0	1	1	1	1	1	1	1	3	1	0	0	2	2	2	1	1	0	0	1	0	1	2	2	3	39
4	9	8	0	0	0	6	5	3	0	0	0	0	0	0	0	0	0	4	10	4	4	2	4	3	3	3	3	2	6	0	0	0	0	0	0	79
5	10	15	1	0	0	10	11	5	0	0	0	0	0	0	0	0	1	3	17	3	9	4	5	5	5	5	5	6	12	1	1	0	0	5	6	144
6	16	23	1	6	10	0	16	8	0	0	0	0	0	0	0	0	1	5	26	5	12	7	8	7	7	8	8	8	18	1	1	0	0	5	6	213
7	16	23	1	10	16	16	0	8	0	0	0	0	0	0	0	0	1	5	26	5	12	7	8	7	7	8	8	8	18	1	1	0	0	5	6	223
8	18	25	2	2	5	7	7	0	0	0	0	0	0	0	0	0	2	8	40	8	11	7	19	13	13	7	7	14	34	0	0	0	0	18	22	290
9	4	8	1	0	0	0	0	0	0	4	4	4	1	1	1	9	0	1	7	1	5	2	3	4	4	2	2	2	5	0	0	0	0	3	3	80
10	4	8	1	0	0	0	0	0	5	0	0	4	1	1	1	8	1	1	7	1	5	2	3	4	4	2	1	2	5	0	0	0	0	3	3	77
11	4	8	0	0	0	0	0	0	4	0	0	4	1	1	1	9	0	2	7	2	5	2	3	4	4	1	2	2	5	0	0	0	0	3	3	77
12	6	13	1	0	0	0	0	0	4	4	4	0	1	1	1	11	1	6	29	6	10	3	4	3	3	0	0	2	5	0	0	0	0	2	3	124
13	9	11	1	0	0	0	0	0	1	1	0	1	0	6	6	1	1	2	11	2	8	3	4	3	3	1	1	5	11	10	1	0	10	3	3	120
14	9	11	1	0	0	0	0	0	1	1	0	1	6	0	6	1	1	2	11	2	8	3	4	3	3	1	1	5	11	8	1	2	10	3	3	120
15	9	11	1	0	0	0	0	0	1	1	0	1	6	6	0	1	1	2	11	2	8	3	4	3	3	1	1	5	11	8	1	2	10	3	3	120
16	12	23	1	0	0	0	0	0	9	8	8	11	1	1	1	0	1	3	16	3	14	7	9	7	7	3	3	6	15	0	0	2	0	7	9	187
17	1	2	0	0	0	0	0	0	1	1	1	1	0	0	0	3	0	0	2	0	2	0	1	1	1	0	0	1	1	0	0	0	0	1	1	22
18	3	6	1	2	4	6	6	8	1	2	2	7	4	4	4	4	0	0	13	0	3	2	10	5	5	2	2	3	6	1	0	1	3	2	3	124
19	14	30	4	11	20	30	30	40	7	7	7	36	18	18	18	20	1	13	0	13	16	7	50	25	25	10	10	15	30	12	1	1	13	10	14	577
20	3	6	1	2	4	6	6	8	1	2	2	7	4	4	4	4	0	0	13	0	3	2	10	5	5	2	2	3	6	0	0	3	3	2	3	125
21	9	0	0	3	7	9	9	10	4	4	4	7	8	8	8	12	1	3	11	3	0	0	4	4	4	2	2	3	8	14	0	1	10	4	5	181
22	5	0	0	2	4	5	5	5	2	2	2	4	4	4	4	6	1	2	6	2	0	0	2	2	2	1	1	2	4	7	0	5	5	2	3	95
23	52	26	3	5	10	15	15	19	3	3	3	4	6	6	6	9	5	9	44	9	5	3	0	14	14	7	7	11	35	10	2	2	10	13	16	400
24	15	5	2	1	4	5	5	10	2	2	2	2	4	4	4	6	1	3	17	3	5	3	12	0	0	3	3	5	12	4	2	3	10	5	5	170
25	15	5	2	1	4	5	5	10	2	2	2	2	4	4	4	6	1	3	17	3	5	3	12	12	0	3	3	5	12	5	2	2	10	5	5	182
26	10	4	1	2	1	2	2	7	1	1	1	0	1	1	1	3	1	2	8	2	3	0	7	4	4	0	0	8	9	1	2	2	7	5	5	107
27	10	4	2	0	2	2	2	7	1	1	1	0	1	1	1	3	1	2	8	2	3	0	7	4	4	3	0	8	9	0	2	1	7	5	5	108
28	4	2	0	2	4	6	6	14	2	2	2	2	7	7	7	6	0	2	12	2	3	1	11	6	6	7	7	0	13	2	4	5	24	5	7	193
29	6	4	0	6	12	18	18	34	5	5	5	5	16	16	16	15	1	5	27	5	9	4	35	13	13	9	9	13	0	3	9	10	40	10	11	408
30	11	16	1	0	0	0	0	0	0	0	0	0	4	4	4	0	1	1	6	1	9	4	6	4	4	1	1	9	19	0	2	0	10	1	2	122
31	2	5	0	0	1	1	1	0	0	0	0	0	1	1	1	0	0	0	2	0	0	0	2	3	3	2	2	4	9	2	0	1	2	2	2	50
32	6	8	1	0	0	0	0	0	0	0	0	0	2	2	2	0	1	1	3	1	5	2	3	2	2	1	1	5	10	0	1	0	5	1	1	61
33	11	20	2	0	0	0	0	0	0	0	0	0	7	7	7	0	1	2	10	2	12	5	10	12	12	7	7	18	40	14	2	5	0	11	11	234
34	14	8	2	2	2	4	4	12	2	2	2	2	3	3	3	6	1	2	8	2	4	2	11	6	6	4	4	5	9	4	2	2	10	0	0	149
35	17	10	2	3	3	5	5	15	2	2	2	2	4	4	4	8	1	2	10	2	5	3	14	7	7	5	5	6	11	6	2	2	12	0	0	188

Total Peak Hour PRT Person Trips	6,202

The daily person trips were then multiplied by 10%, plus a 15% contingency factor, in order to develop the matrix of peak hour trips shown in Table 8. Ten percent of average daily trips is a commonly used factor (confirmed by Jacobs) to determine peak hour trips. Since no data was available regarding the peak hour directional split, one was not applied, but a 15% contingency factor was added. This is to say that the peak hour traffic was assumed to be equal in both directions. This probably underestimates the flows in the vicinity of the gates. However, the flows in the interior of the network are larger and more likely to be equal in both directions.

PRT System Requirements

In order to meet the demands outlined in this report, the PRT system will need to meet the following requirements:

- 18.3 miles of elevated one-way guideway (excluding station access guideways)
- 4.6 miles of at-grade guideway (excluding station access guideways)
- 28 elevated stations
- 7 at-grade stations
- 800 T-Pods, each capable of transporting at least three adults and their luggage, and operating at 25mph, with headways (time between T-Pods) as low as three seconds
- Capable of accommodating a 32% mode share
    - 16.93 million annual passengers
    - 53,500 average daily passengers
    - 6,200 peak hour passengers

In order to determine if the PRT layout depicted in Figure 5 could accommodate 6,200 peak hour passengers, the system was simulated using NETSIMMOD, a proprietary PRT simulation program developed by PRT Consulting. It was found that these passengers can be accommodated at a peak-hour T-Pod average occupancy rate of 2.0 and a minimum operating headway (time between T-pods) of 3 seconds. The average occupancy rate of 2.0 has been assumed, based on the expectation that some ride sharing can be encouraged and will occur – particularly during the peak hour. Stations can be designed to facilitate and encourage ride sharing. In addition (for example), in the evening peak, many trips will have a gate station as a common destination, and riders waiting for a T-Pod are likely to offer to share rides. An off-peak occupancy rate of 1.1 has been assumed, yielding an average occupancy rate of 1.37 (2.0 x 30% + 1.1 x 70%).

The following four tables show NETSIMMOD results from simulations run with differing values for T-Pod occupancy, minimum headway and total number of T-Pods. As can be seen, there are a number of different ways that a PRT system can achieve satisfactory results (average wait time under one minute, less than 10% waiting more than three minutes and in-vehicle delays under 30 seconds). The configuration shown in Table 9 is the one that has been adopted for the purposes of this report. It shows that 700 active T-Pods are required in order to provide satisfactory service levels. In order to allow for contingencies and maintenance needs it has been assumed that a total of 800 T-Pods will be needed.

Table 9. PRT Simulation with 3 second headway, 2.0 occupancy and 700 T-Pods

NETSIMMOD - Data Summary															
Time (min)	Pax Processed	Ave Wait Secs	Max Wait Secs	% Waiting > 1 min	% Waiting > 3 min	No. of T-Pod Trips	Pax Km/ Veh KM	Ave Delay Secs	No. of Inline Stations	No. of Offline Stations	Total Guideway Length	No. of T-Pods	Max T-Pod Occ	Ave T-Pod Occ	Min Headway
0-15	1430	7	264	10	2	503	0.00	0	0	35	41145	700	4	2	3.00
15-30	1578	21	600	26	8	1128	1.60	4	Wave-Offs			Pax KM	Veh KM		
30-45	1567	23	369	29	10	1116	1.52	4	Occ.	Unocc.		34,082	21,925		
45-60	1478	18	423	23	8	1125	1.58	4	0	0					
60-75	1561	14	612	22	2	667	1.51	6							
15-75	6184	19	612	25	7	4036	1.55	5	Max Delay =		34				

The first column of each table shows five quarter-hour (15 minute) time intervals and one, one-hour (60 minute) time interval. The first fifteen minutes (row labeled 0-15) is used for the simulation to settle down. The following four fifteen-minute intervals are summarized in the last row (labeled 15-75). The first column shows the number of people processed. The second column shows the average waiting time in seconds. The third column shows the maximum time anyone had to wait. The system analyzed here needs some optimization, since maximum wait times should not exceed five minutes (300 seconds). The next two columns show the percent of people waiting more than one and three minutes respectively. The No. of T-Pod trips is the total number, including empty vehicle movement. Pax Km/Veh Km is the ratio of passenger kilometers travelled to vehicle kilometers travelled – a measure of actual occupancy including empties. The average delay and maximum delay are in-vehicle delay times. These times account for delays a T-Pod may have in leaving or entering a station.

Table 10. PRT Simulation with 3 second headway, 1.5 occupancy and 800 T-Pods

NETSIMMOD - Data Summary															
Time (min)	Pax Processed	Ave Wait Secs	Max Wait Secs	% Waiting > 1 min	% Waiting > 3 min	No. of T-Pod Trips	Pax Km/ Veh KM	Ave Delay Secs	No. of Inline Stations	No. of Offline Stations	Total Guideway Length	No. of T-Pods	Max T-Pod Occ	Ave T-Pod Occ	Min Headway
0-15	1493	15	273	17	2	1065	0.00	0	0	35	41145	800	4	1.5	3.00
15-30	1475	33	360	32	10	1108	1.28	6	Wave-Offs			Pax KM	Veh KM		
30-45	1551	37	384	39	13	1128	1.39	5	Occ.	Unocc.		34,369	25,765		
45-60	1545	50	636	39	23	1217	1.29	5	0	0					
60-75	1594	47	738	41	16	1182	1.38	6							
15-75	6165	42	738	38	15	4635	1.33	6	Max Delay =		174				

Table 10 shows that reducing the average occupancy (of occupied vehicles) to 1.5 requires approximately one hundred more T-Pods, to reach a similar level of service, to that indicated in Table 9.

Table 11. PRT Simulation with 2 second headway, 2.0 occupancy and 700 T-Pods

NETSIMMOD - Data Summary															
Time (min)	Pax Processed	Ave Wait Secs	Max Wait Secs	% Waiting > 1 min	% Waiting > 3 min	No. of T-Pod Trips	Pax Km/ Veh KM	Ave Delay Secs	No. of Inline Stations	No. of Offline Stations	Total Guideway Length	No. of T-Pods	Max T-Pod Occ	Ave T-Pod Occ	Min Headway
0-15	1368	9	244	16	1	1101	0.00	0	0	35	41145	700	4	2	2.00
15-30	1515	16	246	23	2	1210	1.28	3	Wave-Offs			Pax KM	Veh KM		
30-45	1607	18	626	28	4	1312	1.26	3	Occ.	Unocc.		35,012	26,143		
45-60	1562	10	738	14	0	1206	1.44	3	0	0					
60-75	1576	13	224	18	1	1319	1.38	3							
15-75	6260	14	738	21	2	5047	1.34	3	Max Delay =		72				

Table 11 indicates that reducing the headway to two seconds provides no improvement over Table 9, which had identical parameters, except for a three-second headway. This is an indication that the guideways are not overloaded.

Table 12. PRT Simulation with 2 second headway, 1.5 occupancy and 800 T-Pods

NETSIMMOD - Data Summary															
Time (min)	Pax Processed	Ave Wait Secs	Max Wait Secs	% Waiting > 1 min	% Waiting > 3 min	No. of T-Pod Trips	Pax Km/ Veh KM	Ave Delay Secs	No. of Inline Stations	No. of Offline Stations	Total Guideway Length	No. of T-Pods	Max T-Pod Occ	Ave T-Pod Occ	Min Headway
0-15	1394	15	222	18	1	1133	0.00	0	0	35	41145	800	4	1.5	2.00
15-30	1576	19	374	20	1	1253	1.23	3	Wave-Offs			Pax KM	Veh KM		
30-45	1538	20	294	26	1	1224	1.27	4	Occ.	Unocc.		35,742	27,978		
45-60	1592	34	512	34	8	1233	1.34	3	0	11					
60-75	1585	33	476	35	9	1327	1.27	3							
15-75	6291	27	512	28	5	5037	1.28	3	Max Delay =		107				

Similarly, Table 12 indicates that reducing the headway to two seconds provides no improvement over Table 10, which had identical parameters, except for a three-second headway.

Benefit/Cost Analysis

This section compares the benefits of a PRT system with the costs, in order to determine economic feasibility. While the focus is primarily on quantifiable benefits and costs, those that are difficult to quantify are also addressed.

Capital Costs

PRT System Costs

Our in-house PRT costs model has been used to determine the costs of the proposed PRT system (note that an open-guideway type of PRT system has been assumed throughout this study). These costs have been verified as reasonable through discussions with a number of PRT vendors. The turn-key capital costs of the PRT system, including guideways, stations, T-Pods and control system, are estimated to be $494.30M.

Parking Costs

The cost of providing additional perimeter parking for PRT park-and-ride lots, and the savings in reduced internal parking requirements, are significant factors in the overall cost analysis. A value of $4,000 per stall construction costs has been used (13).

The PRT system will carry 53,500 daily person trips, of which 28,100 will pass through the gates, and 25,400 will be generated internally (12). Half of the through-the-gate trips will be leaving the Post and not require on-Post parking. The other half (14,050) will require parking at the gate. Many people (most notably, soldiers entering the Post for early-morning PT and then leaving for breakfast, and also, possibly, lunch) enter the Post more than once a day. It has been assumed that, on average, people enter the Post twice a day. This means that 7,025 (14,050/2) new parking spaces will need to be provided at the gates at a cost of $28.10M (7,025 x $4,000).

Other Costs

Many Soldiers currently use their automobiles to store their equipment. If they are to use the PRT system, alternative storage may need to be provided. This can possibly be done by providing lockers at the stations. However, no investigation has been undertaken into this situation and no allowance has been made for this in the cost estimates.

Capital Cost Offsets

Road Improvements

The PRT system ridership should be sufficient to reduce future road traffic to levels close to those currently experienced, thus, potentially reducing the need for the following projects (14):

1. Provide 4-lane section along O'Connell Boulevard from Chiles Avenue to Magrath Avenue. $6.21M
2. Provide 4-lane section along Chiles Avenue from O'Connell Boulevard to Prussman Boulevard. $7.67M

3. Provide 4-lane section along Specker Avenue from Prussman Boulevard to Wetzel Ave. $3.62M
4. Provide 5-lane section along Titus Boulevard from Sheridan Avenue to Specker Avenue. $5.67M

These projects total $23.17M. It has been assumed that 50% of this cost ($11.58M) can be eliminated.

Parking Costs

While the PRT system will require additional parking to be provided at gates 1, 2, 3, 4 and 20, it will reduce the amount of parking within the Post by an even larger amount. This is because each automobile typically requires more than one parking space to accommodate its differing needs, such as parking for physical training, parking for daily work location and parking for visits to the store. For PRT trips originating off Post, the number of parking spaces saved per trip is 1.3, based on the assumption that, on average, people enter the Post twice a day and require 2.6 stalls (per Table 1). Trips originating off Post, thus, reduce the internal parking lot requirement by 18,265 (28,100 x 1.3/2) spaces with a cost savings of $74.50M (18,265 x $4,000).

Trips with both origin and destination on Post reduce parking needs an additional amount, if their passengers live on Post (otherwise these trips were accounted for above). Any PRT trip, except trips destined to their domicile, that allows the occupant to leave their car at their residence, reduces the need for one parking space. These trips have been assumed to be those originating in residential zones only (assumed to be TAZs 1, 2, 4, 10, 11, 12, 13, and 17 only). The PRT person trips originating in these zones total 14,604. Each of these trips has been calculated to reduce the internal parking lot requirement by one space for a total of 14,604 stalls, with a cost savings of $58.42 million (14,604 x $4,000).

While it is true that some of the parking area, that will no longer be needed, has already been constructed, it has been assumed reasonable to value the savings at the full construction cost. This is because the reduced parking requirement will allow portions of existing parking lots to be redeveloped as buildings, thus, providing a more valuable use for the land. In addition, such in-fill buildings should improve productivity and further reduce travel needs, by placing more people within walking distance of each other. In addition, the required 82' offset from roads and parking means that eliminating parking stalls frees up land for an alternative use, to a greater extent than the amount of pavement freed up. This benefit has not been quantified here. Finally, to the extent that automobiles are eliminated from congested areas, the threat of vehicle-borne, improvised, explosive devices is reduced.

In summary, the PRT system will cost approximately $522.40M ($494.30 + $28.10M), but this will be offset by an assumed reduction in road and parking expansion, to the extent of $144.50M (11.58 + 74.50 + 58.42M), and the net capital cost of the PRT system to Fort Carson would, thus, be approximately $377.90M. Amortizing this cost over the system's expected forty-year life span (note that the Morgantown PRT system is now 34 years old and projected to function for at least another eight years), at an interest rate of 6%, results in an annual cost of $17.04M.

Operating and Maintenance Costs

The all-inclusive operating and maintenance costs of the PRT system are estimated to be $21.16M per year. These costs have been verified as reasonable through discussions with a number of PRT vendors. They include the (U.S. average) cost of electricity and the cost of maintaining the additional parking required at the gates. The annual cost of pavement maintenance for new parking lots associated with the PRT system has been estimated at 5.0% of the capital cost of these items and is $1.40M per year. Note that assuming a 5% maintenance cost is equivalent to assuming that roads or parking lots will need complete reconstruction, if left totally unmaintained for twenty years. Thus, the total annual PRT operating costs are projected to be $22.56M.

Operating and Maintenance Cost Offsets

Pavement Maintenance

On the benefits side, the PRT system will obviate the need for maintenance of 50% of the road widening and parking projects assumed to no longer be required. Based on 5% (as discussed above), this results in an annual savings of $7.22M. Thus, the net annual operating costs (to Fort Carson) are $15.34M (22.56 - 7.22).

Travel Time

The results of a study comparing PRT and automobile trip times for six different origin/destination pairs are provided in Table 13. PRT in-vehicle trip times were increased by six minutes, to allow for a one minute waiting time and a five minute walking time (1/8th of a mile at each trip end on average). Automobile in-vehicle trip times were increased by three minutes, to allow for a one minute walk at each end and an additional minute for finding parking. The study found PRT trip times (walk, wait and travel) to be 2.5 minutes longer than average (peak and off-peak) automobile trip times (walk, travel and park). The study was undertaken at a time when many soldiers were deployed. Anecdotal evidence (11) indicates that, when most soldiers are on the Post, average automobile trips are delayed by about 5 minutes. It has, therefore, been assumed that PRT travel provides a small (but not quantifiable) net time benefit or cost, under present conditions. Note that the fact that PRT travelers can safely occupy themselves with meaningful tasks is a benefit that has not been quantified here.

Travel time delay data, provided by Jacobs (12) and based on the Post's Comprehensive Transportation Study (14), indicates that, at build-out, automobile travel will suffer average delays of 1.61 minutes. While this may not seem significant, it should be realized that this average is made up of off-peak trips suffering no delays and peak trips suffering quite significant delays. Since the PRT system will significantly reduce growth in automobile travel, it has been assumed it will eliminate these delays for 50% of the 215,000 daily on-Post trips. At a delay cost of $18.57 per hour in lost time and wasted fuel (16), this amounts to an annual cost savings of $13.07M (215,000 x 50% x (1.61/60) x 18.57 x 244 working days).

Table 13. Trip Time Comparison

Actual Drive Time (Average)						PRT			
Zone	To Zone	Distance (mi.)	Travel Time (h:mm:ss)	Walk/Find Parking Time (m:ss)	Total Time (h:mm:ss)	Distance (mi.)	Transit Time at 23 m.p.h. (h:mm:ss)	Walk / Wait Time (mm:ss)	Total Time (mm:ss)
1	12	4.0	12:40	3:00	15:40	4.8	12:31	6:00	18:31
12	1	4.5	16:38	3:00	19:38	4.0	10:26	6:00	16:26
Gate 1	21	3.1	7:52	3:00	10:52	4.6	12:00	6:00	18:00
21	Gate 1	2.5	8:43	3:00	11:43	2.4	6:16	6:00	12:16
4	20	2.4	7:47	3:00	10:47	2.7	7:03	6:00	13:03
20	4	2.8	9:02	3:00	12:02	4.5	11:44	6:00	17:44
1	7	2.9	11:30	3:00	14:30	5.7	14:52	6:00	20:52
7	1	2.9	11:56	3:00	14:56	4.2	10:57	6:00	16:57
2	12	3.4	10:37	3:00	13:37	3.7	9:39	6:00	15:39
12	2	3.2	11:55	3:00	14:55	2.6	6:47	6:00	12:47
20	21	1.3	5:08	3:00	8:08	2.4	6:16	6:00	12:16
2	17	2.3	8:26	3:00	11:26	3.6	9:24	6:00	15:24
7	21	4.7	14:15	3:00	17:15	5.2	13:34	6:00	19:34
Totals		40.0	2:16:29	39:00	2:55:29	50.4	2:11:30	1:18:00	3:29:30
Average trip time					13:30				16:07
Average in-vehicle time			10:30				10:07		
Average trip speed (mph) including all times:				13.7				17.2	

In addition, a PRT system is expected to provide considerable winter storm benefits to the Post. The Morgantown PRT system is often the only transit system operating during major storms. Vectus has recently published a video, demonstrating unimpaired operations in snowy conditions (see Figure 14), and ULTra has a guideway option, utilizing a grating riding surface, that allows snow to fall through, while maintaining high friction values.

In calculating the cost savings, the following assumptions have been made:

- 23 winter storms occur every year where snowfall exceeds one inch (15).
- Without a PRT system, 30% of the 215,000 daily on-Post trips suffer a 10-minute snow delay at a cost of $15.30M (215,000 x (10/60) x 18.57 x 23).
- The PRT system accommodates 53,500 trips without delay.
- The PRT system reduces traffic and the remaining 161,500 trips suffer a 5-minute snow delay at a cost of $5.75M (161,500 x (5/60) x 18.57 x 23).

Figure 14. Vectus operating at full speed in snow.

The resulting cost savings total $9.55M (15.30 – 5.75) annually. Thus, the total travel time savings are $24.89M.

Reduction in Automobile Costs

The average PRT trip length is anticipated to be 3.9 miles and is assumed to replace one automobile trip of 3.0 miles at an occupancy of 1.1. The annual cost savings are $27.48M (16.93M x 3.0 x $0.541) based on 54.1¢ per mile (8). Not that this cost savings will accrue to Fort Carson to the extent that auto trip reduction comes from Fort Carson's fleet.

Reduction in On-Post Emissions

The PRT system will replace some 50.79M annual automobile VMT with approximately 66.27M annual electric VMT. The automobile VMT will actually be comprised of a mix of vehicles, but has been assumed to consist only of average cars. Greenhouse gas damage costs for average cars are $0.147 per average car VMT and $0.037 per average electric vehicle VMT (16). These costs reflect lifecycle emissions, including emissions during petroleum extraction and refining, vehicle manufacturing and maintenance, as well as roadway construction and maintenance. The cost saving for reduced automobile use amounts to $7.47M (50.79M x $0.147) and the extra cost for T-Pods is $2.45M (66.27M x $0.037). Thus, the net annual savings is $5.02M.

Savings in Accident Costs

PRT Consulting's Muller (17) found that PRT is approximately 100 times safer than other modes in a university campus environment. While the environment on the Post is thought to be similar, a factor of ten times has been used in order to be conservative. For a small metropolitan area, the cost of crashes is 41¢ per vehicle mile (18). Since the PRT system will reduce annual VMT by about 50.79M and will reduce accidents by 90%, the annual savings in accident costs is estimated to be $18.74M (50.79M x .90 x $0.41).

Summary

The net annual costs of the PRT system are as follows:

Costs:

Annualized net capital costs	$17.04M
Annual net O&M cost	$15.34M
Total annual costs	$32.38M

Benefits (savings):

Savings in travel time	$24.89M
Savings in automobile costs	$27.48M
Savings due to emission reductions	$5.02M
Savings in accident costs	$18.74M
Total annual savings (benefits)	$76.13M

The benefit/cost ratio is 2.35. This indicates a significant benefit and implies that large changes would need to be made in the data, analysis and/or assumptions used, for this proposed PRT system not to be feasible from a benefit/cost point of view.

Note that the proportions to which the above benefits accrue to the USAG, society and individuals are difficult to determine, and no attempt has been made to do so. However, it seems reasonable to infer that the benefits accruing to most individuals should outweigh any fare required to cover the total annual costs of $32.38M – particularly in light of the fact that federal employees qualify for a $230 transit allowance.

In order for fares to cover all costs, each of the 16.93M annual passengers would need to pay a fare of $1.66 per ride. This seems reasonable since RTD charges $2.00 for trips averaging 1.9 miles, while the PRT trips are anticipated to average 3.0 net miles. This is especially true when considering that federal employees receive a $230 per month transit allowance which would cover 138 trips per month at $1.66 per trip. If each of the 29,034 active military personnel were to purchase a $230 monthly pass, this would generate $80.14M annually.

25% Mode Share

For comparative purposes, the above analysis was repeated with the PRT system carrying a mode share reduced from 32% to 25% with the following results:

System requirements were reduced to 600 T-Pods carrying 13.23M annual, 41,800 daily and 4,700 peak hour passengers.

Costs:

Annualized net capital costs	$16.33M
Annual net O&M cost	$11.82M
Total annual costs	$28.15M

Benefits (savings):

Savings in travel time	$17.70M
Savings in automobile costs	$21.47M
Savings due to emission reductions	$3.91M
Savings in accident costs	$14.64M
Total annual savings (benefits)	$57.72M

Benefit/Cost Ratio 2.05

Required fare $2.13 per ride

50% Mode Share

Increasing the mode share from 32% to 50% had the following results:

System requirements were increased to 1,200 T-Pods carrying 26.41M annual, 83,600 daily and 9,400 peak hour passengers. Some adjustments to the guideway network were required.

Costs:

Annualized net capital costs	$16.12M
Annual net O&M cost	$24.11M
Total annual costs	$40.23M

Benefits (savings):

Savings in travel time	$30.15
Savings in automobile costs	$42.86M
Savings due to emission reductions	$7.82M
Savings in accident costs	$29.24M
Total annual savings (benefits)	$110.07M

Benefit/Cost Ratio 2.75

Required fare $1.52 per ride.

Conclusions and Recommendations

Based on the preliminary study undertaken, a PRT system at Fort Carson appears to be feasible and has a highly favorable benefit/cost ratio. Most remarkably, it appears that the potential fare-box revenue could not only cover the operating costs, but also the annualized capital costs. This is unheard of in conventional public transit, where fares are typically subsidized, just to cover operating costs.

To put this project in perspective, it is compared to the recently-funded Salt Lake City Mid-Jordan Light Rail Extension (19) and the Dulles Rail Project (20) in Table 14 below.

Table 14.

	Mid-Jordan LRT Extension	Dulles Rail Project	Fort Carson PRT Project
Miles of track	11 (two-way)	23 (two-way)	23 (one-way)
Stations	9	11	35
Daily passengers	9,500	60,000	53,500
Capital cost	$428,300,000	$5,200,000,000	$522,400,000[1]
Cost per mile[2]	$19,468,000	$113,000,000	$22,713,000
Cost per station	$47,590,000	$472,700,000	$14,926,000
Cost per annual passenger[3]	$150	$290	$33

Clearly this appears to be a very viable transit project. However, this initial study was of limited scope and did not address all issues, nor was the work undertaken of sufficient depth to provide a fully credible result. In addition, while the project is economically viable, funding and financing mechanisms need to be established before it can proceed.

While funding and financing are key hurdles to be overcome, it appears that these may not be insurmountable obstacles. The PRT project could obviate the need for some $11M presently-planned road expansion projects, and these funds could potentially be used to seed the project. Total annual net operating and capital costs are $32.38M. To cover the cost, each of the 16.93M annual passengers would need to pay a fare of $1.66. This fare-box revenue could be used to finance the project, but fares by themselves are typically insufficient for bonding of conventional transit projects.

It appears that this project will pay for itself in deferred capital and operating costs, for other projects no longer needed and in revenues from fares. However, mechanisms for utilizing the savings and revenues to finance the project will have to be found.

Note that RTD charges $2.00 for light rail trips averaging 1.9 miles in length ($1.05 per mile). Thus, a fare of $1.66 for the PRT system, with average trip lengths around 3 miles, seems reasonable. In addition,

[1] Total cost excluding capital cost offsets
[2] One-way
[3] Daily passengers x 300

this study indicates that personal and societal savings in costs, related to time, automobile ownership, operations and maintenance, and accidents, will substantially outweigh the fare.

It should be noted that this report attempted to quantify savings resulting from reduced parking needs, and these savings were used to partially offset the capital cost of a PRT system. Further study is needed to evaluate these potential savings, to determine how best to take advantage of the denser land use enabled by PRT and how to turn these benefits into funding sources for a PRT system.

If the USAG-Fort Carson decides to proceed with this project, the following steps are recommended:

1. Move quickly. Some of the benefits outlined will erode if the Post continues to develop in a way that encourages sprawl and if it is forced to undertake road widening and parking projects to meet growing demand. The first step should be to prepare a time-line for the following steps and to determine which can occur concurrently. The ability of a PRT system to be implemented in time to meet the anticipated growth is a key factor yet to be determined.
2. Expand this study into a comprehensive PRT Feasibility Study, including the following tasks, some of which have been addressed in preliminary form in this study:
    a. Public Participation
    b. Alternatives Evaluation Including Off-Post Expansion
    c. Ridership (including PRT incentive, automobile disincentive program)
    d. System Performance
    e. Technology Assessment
    f. Price Sensitivity
    g. Code Compliance
    h. Cost Estimates
    i. Implementation Plan, Funding and Financing Options

    In addition to pointing the way forward, the resulting document should provide a detailed PRT system layout depicting station sizes and guideway routings, indicating which portions of the system can be at grade and which need to be elevated. This work should be sufficiently detailed to allow the adjoining areas to be compatibly developed, but not so detailed as to unreasonably eliminate specific PRT vendors from competing for the project. The study needs to be undertaken, in conjunction with a master planning study that amends the planned development and expansion of the Post, to take full advantage of the improved land-use options enabled by a PRT system.
3. Undertake any environmental work and/or other compliance work determined necessary under item 1 (g) above.
4. If it is still desired to proceed, prepare bridging documents for procurement of a PRT system under the procurement methods determined most appropriate under 1 (i) above.
5. Implement funding and financing mechanisms as recommended under 1 (i) above.
6. Enter into a contract(s) for system design, construction, manufacture, installation, testing, commissioning, operation and maintenance.

This study has shown that a PRT system could bring significant benefits to the Soldiers and people living and/or working on the Post. When monetized, these benefits far outweigh the system's costs. A PRT system would go a long way towards allowing the Post to meet its transportation-related sustainability goals. The sprawling nature of the present development on the Post is such as to not be conducive to a PRT system. The positive results of this study are, thus, somewhat surprising and indicate a potential for PRT to have beneficial transport and sustainability impacts in other military or civilian developments of similar type.

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